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Function Selection with the Tablet: The Effect of Labels for Visual Cuing

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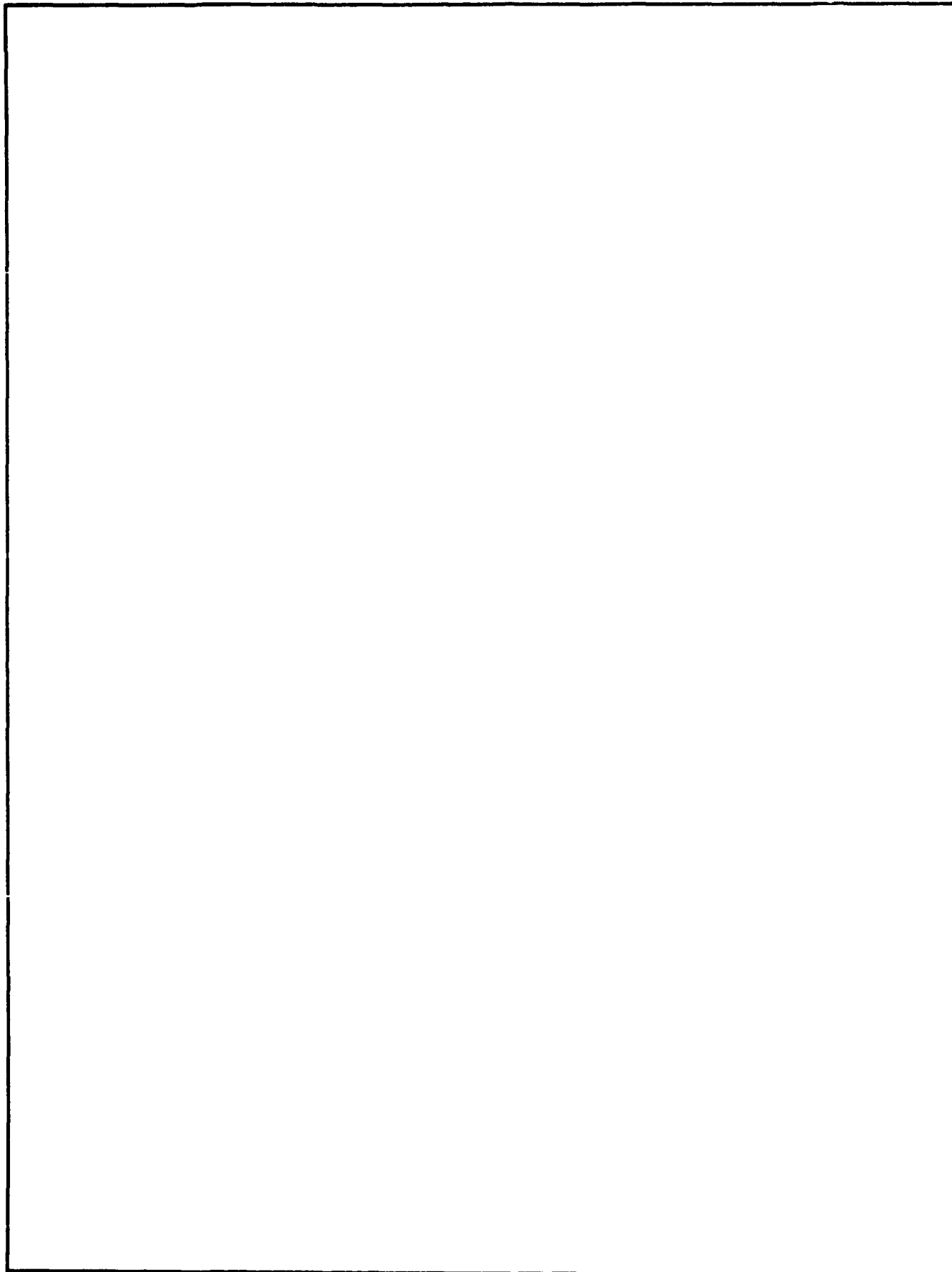W.T. Rasmussen, Head
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The present study assessed the effects of visual cuing on function selection performance using a fully labeled, a partially labeled and an unlabeled touch sensitive digitizer tablet. The fully labeled tablet duplicated the visual display of function names and zones shown on the CRT which was used to present the task. The partially labeled tablet presented only the outlines of the function areas, while the unlabeled tablet provided no visual cuing on the tablet surface.

Subjects provided with tablet labeling (either full or partial) performed the task more rapidly and with fewer errors than the no labeling group. No significant differences were found between the partial and full-labeling groups, or between men and women who performed this task.

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Introduction

Research and development in the area of human-computer interaction has greatly increased the interface options available to system designers as well as computer users. With new input devices and variations on existing devices being produced, interaction methods have become creative and diverse. Those methods that can capitalize on natural modes of communication (pointing, for example) make human-computer interaction more comfortable and efficient (Ohlson, 1978; Pfauth & Priest, 1981).

The present study dealt specifically with the digitizing tablet, one of the most natural and versatile input devices. Generally considered a locator device, the tablet can be used to simulate a button device for simple selection (Ohlson, 1978). In addition to locator and button, Foley and Wallace (1974) used the terms valuator and pick to group input devices into categories based on function. Foley and Van Dam (1982) added keyboards as a fifth category.

Locator devices are used to obtain position information in a coordinate space; examples of locators include the joystick, mouse, trackball, touch screen,

and tablet. Buttons process function-identification information. Programmed function keys are a common button device used to select from a group of options. Devices of the valuator class process numerical or value information; rotary and slide potentiometers are examples. Pick devices are used to process object-identification information. The light pen is the only 'natural' pick device (Foley & Van Dam, 1982). Keyboards process text or character information.

Pfaff, Kuhlmann, and Hanusa (1982) offered a slightly different grouping of input devices. Their set of logical input devices consisted of locator, valuator, choice, pick, string, and stroke. The groups map from physical devices to logical values: a pair of coordinates, a real value, an integer number, a segment name and pick identifier, a character string, and a sequence of coordinate pairs, respectively.

As with input devices, categories of input tasks have been proposed (Ramsey & Atwood, 1979; Foley, Wallace, & Chan, 1981). The five main types of input tasks are, according to Ramsey and Atwood (1979): text input, numerical input, command or operand selection, discrete positional input, and continuous positional input. A variety of options are available for performing these tasks. Combinations of input devices and input tasks include: using a light pen to point,

using a touch screen to point, using a tablet to position the cursor, and pressing a programmed function key. Foley et al. (1981) provided examples for each type of input task but qualified the lists by stating that the number of possible techniques is limited only by one's imagination.

The tablet is a device capable of performing all of the major types of input tasks. Although tablets are often categorized as merely graphics devices for sketching and tracing (Ritchie & Turner, 1975; Kantowitz & Sorkin, 1983) they can accomplish diverse tasks. Pobgee and Parks (1971) explained the development and use of CHIT (CHeap Input Tablet), designed to provide simple low-cost data input. CHIT's three modes of operation - drawing, pointing, and interactive - take advantage of the tablet's versatility.

The various types of tablets available are described by Ohlson (1978) and Scott (1982); included are electromagnetic, sonic (acoustic), and touch tablets. They are differentiated by the principle used to determine location on the tablet.

Touch-sensitive tablets allow operation with a finger or an unsensitized stylus. The tablet surface detects the finger or stylus as x and y analog values. A control unit then converts the analog values to

digital xy position coordinates. The touch screen, an on-display device, is very similar to the touch tablet, an off-display device.

A number of sources have assessed on-display and off-display touch input devices in terms of their advantages and disadvantages. One of the disadvantages common to early on- and off-display panels was the requirement of a captive stylus permanently connected to the circuitry. As a result, the Analog Touch Panel as well as other devices were designed to provide simple touch operation (Turner & Ritchie, 1973).

In an air traffic control application, Johnson (1967) cited touch screens as being faster and more accurate than keyboards; it was easier to point to a call sign on the screen than to type in a 5-7 character string. Ng and Puchkoff (1982) gave two advantages of touch screens over finite, hard coded function keys. Programmable displays make function selection flexible and do not require the transfer of eye and hand to special keys. Pfauth and Priest (1981) listed additional advantages of touch screens: input/output to one location, minimal training or memorization required, high operator acceptance, symbolic/graphical representation, and minimal eye-hand coordination problems.

Disadvantages of touch screen devices include less flexibility for some input tasks, parallax problems, physical fatigue from reaching, and the finger obscuring displayed items (Pfauth & Priest, 1981). Mis-registration of the touch point due to display drift (Ball, Newton, & Whitfield, 1980) and very limited gross resolution capabilities (Ohlson, 1978) are also negative aspects.

The advantages of touch tablets have received less attention. Ball et al. (1980) advocated off-display touch devices because they do not suffer the disadvantages of on-display devices: the hand does not obscure part of the display, there are no parallax problems, and drift in the display is not a concern. In general, touch tablets are easy to use and require little learning (Mims, 1984). Swezey and Davis (1983) stated that the major disadvantage of the tablet is its remoteness from the display. This may actually be an advantage; since the tablet surface and display are separate they can be optimally positioned for comfort and ease of viewing (Whitfield, Ball, & Bird, 1983). Additionally, tablet labeling for certain tasks would make direct eye-hand coordination possible.

Literature on the investigation of touch tablet use is limited. Input device comparisons can benefit device selection for specific purposes but offer little

information for their design and creative application. Albert (1982) compared seven devices (touch screen, lightpen, trackball, position joystick, force joystick, keyboard, tablet) in a cursor positioning task but also considered two design characteristics: whether a separate enter switch (footswitch) was used and whether direct eye-hand coordination was used. Accuracy and speed were measured for each of ten within-subjects conditions. Included in the different conditions were an on-display touch screen with footswitch, an adjacent-to-display touch screen with footswitch, an on-display touch screen without footswitch, and a tablet with footswitch. The on-display and adjacent-to-display touch screens were used to compare direct versus indirect eye-hand coordination. It would be possible to interpret the adjacent touch screen, mounted on a second CRT, as a vertically-oriented touch tablet.

The results showed that direct eye-hand coordination was important for speed; faster positioning speeds were recorded for the on-display touch screen than for the adjacent-to-display touch screen. There was no difference in accuracy between the two conditions. The tablet, used with a puck, ranked fifth among the ten conditions for positioning speed and ninth for positioning accuracy. The touch screen without

footswitch was the fastest device in the experiment but also the least accurate.

While these results show a clear speed/accuracy trade-off, they can only be applied to finer positioning tasks. In tasks which do not require fine positioning movements, as with function selection, touch input devices can be both fast and sufficiently accurate.

Whitfield et al. (1983) reached the same conclusion in a comparison of on-display and off-display touch input performance. A series of three experiments were conducted with increasing target resolution requirements. Each experiment used a cursor positioning task; subjects moved the cursor to a brightened target on the screen. Response times and error rates were recorded.

In experiment one (low resolution) the subject was instructed to select a menu item from a 4 X 3 matrix on the display. The input devices compared were a touch screen, touch tablet, and touch tablet with separate enter key. Position entry with the first two devices was accomplished by finger lift-off. Response times and error rates were higher for the touch tablet than for the touch screen and touch tablet with separate entry. Fall-out type of errors were a problem with the tablet requiring lift-off entry. Changes were made in

the software to help reduce fall-out errors in the second and third experiments.

Subjects in experiment two (medium resolution) selected items from a 16 X 16 tabular display. Only the touch screen and the touch tablet with lift-off entry were compared. As in experiment one the touch tablet was significantly slower than the touch screen. For this task, however, the tablet had a lower error rate.

The third experiment (high resolution) used a target acquisition paradigm to compare performance with a touch screen, touch tablet, and trackball. With regard to response time the touch screen was fastest, followed by the touch tablet and trackball. The trackball produced a significantly lower error rate than either of the touch input devices.

Whitfield et al. (1983) concluded that except where high levels of resolution (or positioning accuracy) are necessary, touch input devices "should have extensive practical application" and that performance differences between on- and off-display touch devices are negligible. The choice of an off-display touch tablet can be justified in numerous applications where touch input is desired.

One such application for touch tablet use is function selection. Program function keyboards are

widely used for this task but their only role is the selection of control options; other input devices must be available for positioning and pointing operations (Scott, 1982). The necessity of more than one input device may not be cost-effective and can result in a mode mixing effect (Ramsey & Atwood, 1979). Alternating between input devices was shown to have a detrimental effect on performance by Earl and Goff (1965).

Other common methods for performing function selection include typing an option on the display screen and pointing at an option (either directly or by cursor positioning). "Point-at" methods of entry in general are faster and more accurate than type-in methods (Earl & Goff, 1965; Johnson, 1967; Seibel, 1972). Gade, Fields, Maisano, Marshall, and Alderman (1981) compared type-in and point-at (menu selection) entry methods. The pointing method was found to "reduce cognitive errors (e.g., incorrectly encoding information) as well as typographical errors (incorrectly entering properly coded information)." Gade et al. (1981) concluded that selecting entries from menus is both cognitively and behaviorally simpler than typing in entries.

Using the touch tablet to point at fixed functions can be an efficient method of input and a means to

avoid mode mixing. The versatility of the touch tablet makes it possible to perform function selection as well as other tasks with the same input device. It also makes it possible to select functions by different methods. Function selection with an unlabeled tablet requires cursor positioning where eyes and hand work separately. Function selection with a labeled tablet allows for direct pointing and eye-hand coordination.

The use of overlays for tablet labeling has been noted in the literature (Pobgee & Parks, 1971; Sutherland, 1974; Scott, 1982; Long, Whitefield, & Dennett, 1984), but the effects of this visual cuing on performance have not been studied. Research in this area can provide much-needed information for input device design and operation and result in more efficient human-computer interaction in a variety of applications.

Hypotheses

This study was performed to determine the effect of visual cuing on function selection performance using students in introductory psychology courses. Three levels of tablet labeling were included in the experiment: no labeling, partial labeling (outlined tablet), and full labeling. A sex factor was also included in the experiment.

It was hypothesized that tablet labeling would produce a significant main effect. The full labeling condition was expected to produce the fastest and most accurate responses, followed by partial labeling and no labeling. A significant sex effect was not anticipated. Previous research with the touch tablet found no main effects for sex (Ellingstad, Parng, Gehlen, Swierenga, & Auflick, 1985).

Method

Subjects

Thirty-six subjects, eighteen male and eighteen female, were tested in this experiment. The number of subjects needed to achieve a power of .80 was derived from a power table in Kirk (1982); it was based on the low error rates expected for the function selection task. Ellingstad et al. (1985) reported error rates of approximately 5% for touch tablet use in varied tasks.

Subjects 18-30 years of age were solicited from undergraduate psychology courses at the University of South Dakota. They received extra credit points in their classes for participating. All were tested to confirm 20/20 corrected visual acuity. An informed consent form was read and signed by each subject (see Appendix A).

Apparatus

Visual acuity was tested with an American Optical Company Sight Screener Model 1810A. A monitor and touch-sensitive digitizer tablet were used as part of a simulated Lightweight Modular Display System (LMDS) which was designed for surface command and control operations (Gomez, Davenport, Wolfe, & Calder, 1982).

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The tablet used was the Model E233 H/GT digitizing tablet manufactured by Elographics, Inc. Approximately four ounces of pressure were needed on the 11" X 11" active surface area for operation. The tablet overlays consisted of unlabeled and labeled sheets of paper which were double-laminated. A general purpose controller, Model E271-60 from Elographics, Inc. was the interface between the tablet and microcomputer. The controller digitizes x and y analog signals detected from the tablet and transmits them to the computer. The monochromatic display used in the function selection task was shown on an Amdec Color II RGB monitor.

The computer system consisted of an IBM 5150 PC with dual disk drives and an Okidata 83A dot matrix printer. Pascal was the programming language used to write the necessary software.

Procedure

Subjects were randomly assigned to one of three groups - no labeling, partial labeling, or full labeling - resulting in 12 subjects per group (6 male and 6 female). Subjects received a general instruction sheet before beginning the session (see Appendix B).

The task consisted of selecting the function specified in the center of the screen at the start of

each trial. Six functions were vertically listed and outlined on each side of the display screen, and either a blank, partially labeled, or fully labeled overlay was used on the tablet (see Appendix C). A control/display ratio of approximately 1.24 was used.

In the no labeling condition the selection required positioning the cursor anywhere in the specified function's outlined area on the display. Positioning was accomplished by the subject moving his or her finger, using the preferred hand, on the touch tablet surface to affect cursor movement into the function area. In all three conditions a selection was confirmed when the finger was lifted off the tablet. After confirmation occurred there was a 2 second delay before the next function to be selected was displayed. The specified functions appeared in a randomized order.

Function selection was aided by visual cues in the partial labeling condition. An outline of the function areas shown on the display screen was incorporated in an overlay placed on the tablet. In the full labeling condition the overlay was identical to the display layout. Selecting a function could be accomplished by touching the specified function's area on the tablet.

Each subject completed two blocks of twenty-five practice trials, followed by four more blocks of twenty-five trials each. Subjects received feedback on

their performance between trial blocks via the display screen. They were asked to perform the task as quickly and as accurately as possible.

Experimental Design

A three-factor repeated measures design was used. The two between-subjects variables were tablet labeling (none, partial, or full) and sex of subject. Blocks of trials were included as a within-subjects factor. Analyses of variance and multiple comparison tests were performed on the data.

Performance Measures

Response times and errors per trial were the measures of function selection performance. The timing for each trial began when the function first appeared and ended with finger lift-off. An error was recorded each time the subject entered an unspecified function or lifted off before having the cursor positioned in the specified function's area.

Subjects completed a brief questionnaire after the testing session to provide information on where they focused their attention during the selection task (see Appendix D).

Results

Mean response times (MRT) and mean errors (ME) for
all blocks and labeling conditions are summarized in
Table 1. Blocks P1 and P2 consisted of practice trials
and were not included in the analyses.

Separate analyses of variance were performed for the
two dependent measures. Each employed a three-factor
repeated measures design consisting of two between-
subjects variables (labeling and sex) and one within-
subjects variable (block). The results of the analysis
of variance for MRT are shown in Table 2. Significant
main effects were found for both labeling ($F_{(2,30)}=$
33.14, $p< 0.0001$) and block ($F_{(3,90)}= 27.55$, $p<$
0.0001); alpha = .05. No significant sex effect or
interactions were found.

Scheffe's multiple comparison test was used to
examine the significant main effects from the mean
response time analysis. The no labeling condition had
a significantly higher mean response time (2.44 sec.)
than either of the other two levels of labeling. The
full labeling condition produced the lowest mean
response time (1.56 sec.) but was not significantly
different from the partial labeling condition (1.77
sec.). Figure 1 is a graph of MRT by labeling and sex.

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TABLE 1

MRT and ME for All Blocks and Labeling Groups

| | LABELING | | | | | | Across Groups | |
| | None | | Partial | | Full | | | |
Block	MRT	ME	MRT	ME	MRT	ME	MRT	ME
P1	3.29 (.77)	.25 (.15)	2.31 (.41)	.05 (.04)	2.21 (.39)	.03 (.06)	--	--
P2	2.72 (.45)	.09 (.09)	1.95 (.39)	.03 (.03)	1.72 (.23)	.01 (.02)	--	--
1	2.62 (.28)	.09 (.09)	1.94 (.30)	.02 (.03)	1.68 (.24)	.04 (.04)	2.08	.05
2	2.42 (.27)	.10 (.09)	1.80 (.26)	.02 (.03)	1.61 (.29)	.01 (.03)	1.94	.05
3	2.43 (.37)	.05 (.09)	1.70 (.30)	.04 (.07)	1.52 (.23)	.01 (.02)	1.88	.04
4	2.28 (.47)	.05 (.07)	1.64 (.33)	.03 (.04)	1.43 (.23)	.02 (.03)	1.78	.03
Blocks 1-4	2.44	.08	1.77	.03	1.56	.02		

Note: Standard deviations are presented in ( ) below their means.

TABLE 2

Analysis of Variance for MRT

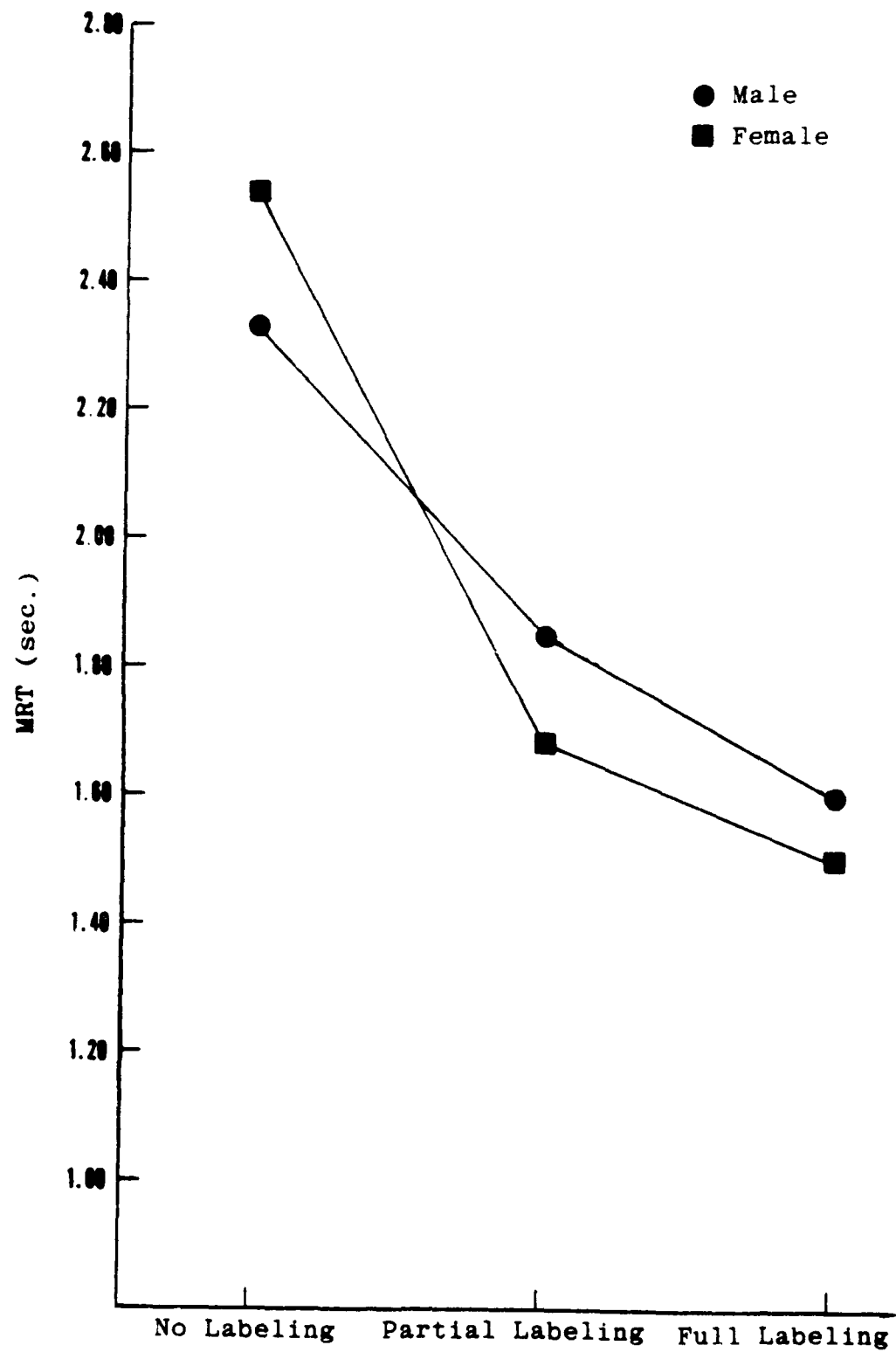| Source	df	SS	MS	F	p
Between Subjects					
Label	2	20.252	10.126	33.14	<0.0001
Sex	1	0.014	0.014	0.04	<0.8352
Label*Sex	2	0.972	0.486	1.59	<0.2207
Subj w.groups	30	9.167	0.306		
Within Subjects					
Block	3	1.708	0.569	27.55	<0.0001
Label*Block	6	0.085	0.014	0.69	<0.6606
Sex*Block	3	0.053	0.018	0.86	<0.4680
Label*Sex* Block	6	0.270	0.045	2.18	<0.0524
Block*Subj w.groups	90	1.860	0.021		

Figure 1: MRT by Labeling and Sex

Scheffe tests examining the block effect indicate that after the two blocks of practice trials the mean response time continued to decrease slightly. The mean response time for block 1 (2.08 sec.) was significantly higher than for the rest of the blocks. A significantly lower mean response time was recorded for the last block (1.78 sec.) than for all of the preceding blocks. The difference in mean response time between blocks 2 (1.94 sec.) and 3 (1.88 sec.) was not significant. Mean response times are graphed by block and labeling group in Figure 2.

The analysis of variance for ME is summarized in Table 3. Only the main effect for labeling was found to be significant $(F (2,30)= 8.04, p< 0.0016)$.

Scheffe's multiple comparison tests for the labeling effect indicated that the mean error rate for the no labeling condition (.08 errors) was highest and was significantly different from the partial (.03 errors) and full (.02 errors) labeling conditions. While the mean error rate generated in the full labeling condition was lowest, it was not significantly different from the partial labeling mean error rate. Figure 3 is a plot of ME by labeling and sex.

The questionnaire which was completed by each subject after the testing session consisted of two questions. Each question offered two possible
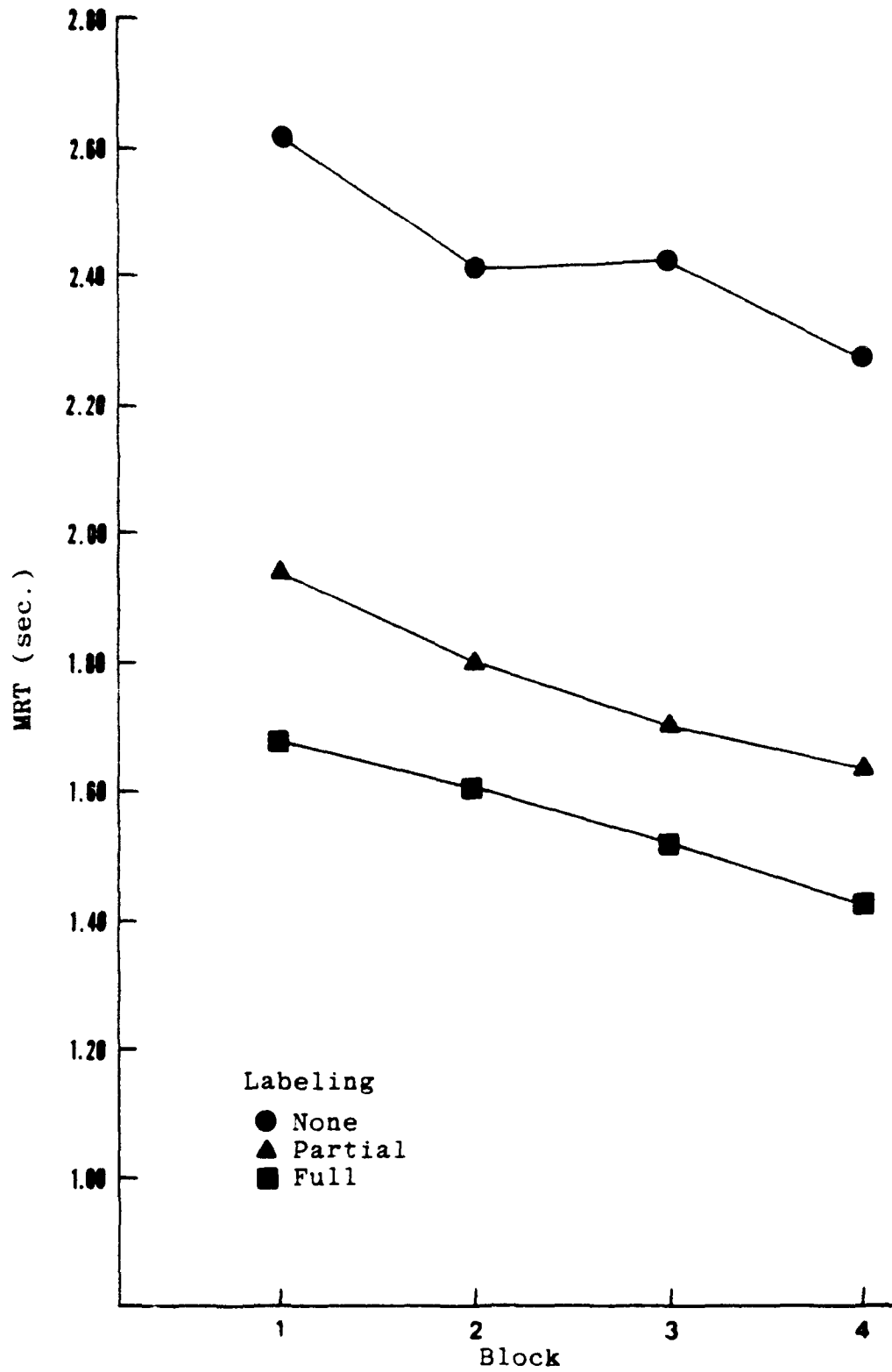
Figure 2:   MRT by Block and Labeling

TABLE 3

Analysis of Variance for ME

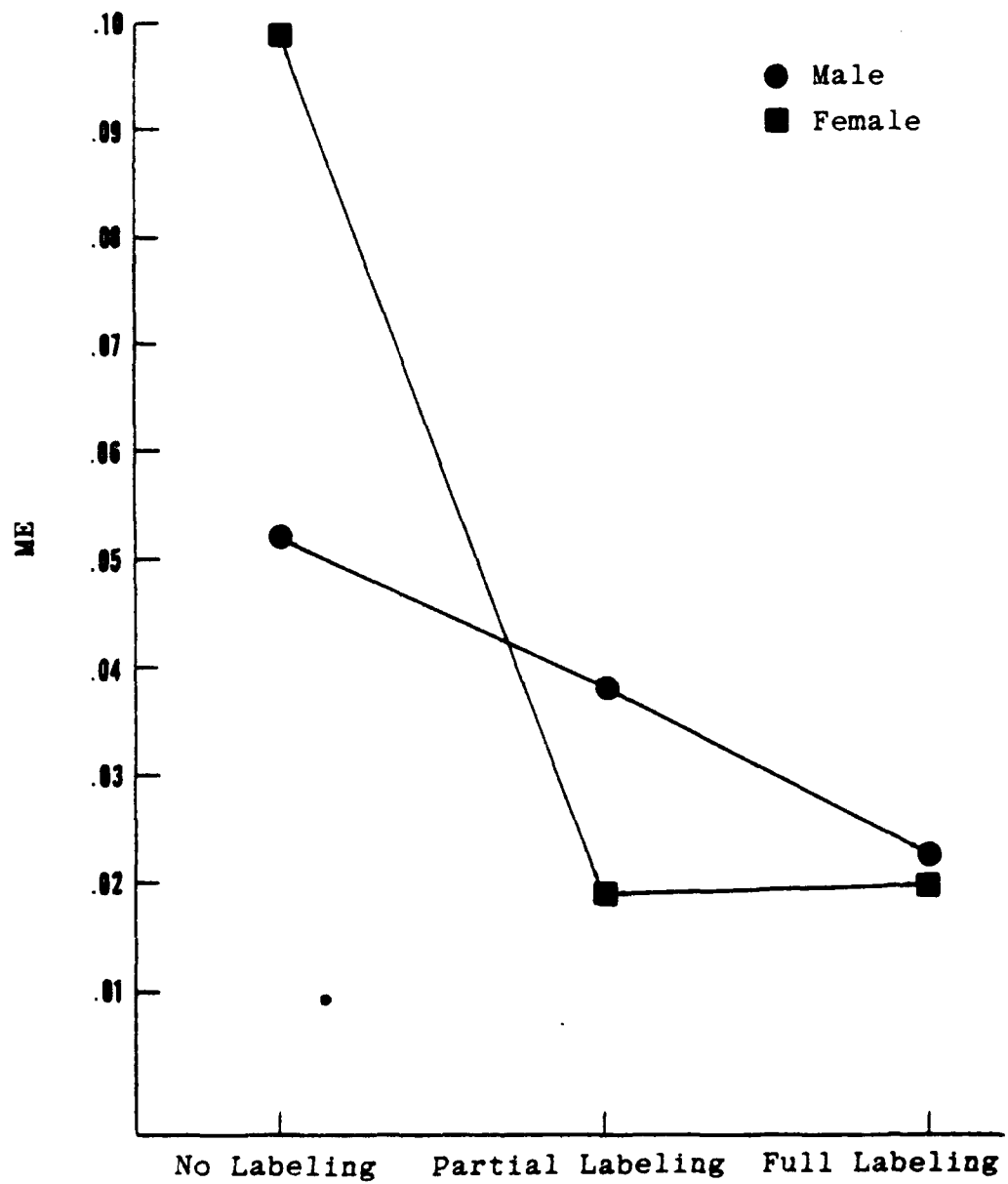| Source	df	SS	MS	F	p
Between Subjects					
Label	2	0.082	0.041	8.04	<0.0016
Sex	1	0.003	0.003	0.49	<0.4896
Label*Sex	2	0.028	0.014	2.72	<0.8210
Subj w.groups	30	0.153	0.005		
Within Subjects					
Block	3	0.005	0.002	0.69	<0.5642
Label*Block	6	0.027	0.005	1.81	<0.1066
Sex*Block	3	0.004	0.001	0.49	<0.6948
Label*Sex*Block	6	0.012	0.002	0.76	<0.6004
Block*Subj w.groups	90	0.226	0.003		

Figure 3: ME by Labeling and Sex

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responses: 'on the screen' or 'on the touch tablet'.
The first question asked the subjects where they
searched for the specified function. Eleven of the
subjects in the no labeling condition and all twelve in
the partial labeling condition responded that they
searched on the screen. One subject in the no labeling
condition mistakenly answered that the specified
function was searched for on the unlabeled tablet. The
responses to question one were split evenly between 'on
the screen' and 'on the touch tablet' for subjects in
the full labeling condition.

For the second question the subjects were asked
where they focused their attention while selecting the
function. All of the subjects in the no labeling
condition, which required cursor positioning, responded
that they focused their attention on the screen. The
majority of the subjects in the partial and full
labeling conditions, which allowed for direct pointing,
responded 'on the touch tablet'. Each subject's
performance on the function selection task was observed
for the first few practice trials. Although three of
the twelve subjects with the partially labeled tablet
and five of those with the fully labeled tablet
reported that they focused their attention on the
screen, all of the subjects in these conditions were
observed to use direct pointing rather than cursor
positioning to make the selections.

Discussion

The purpose of this research was to investigate the effect of tablet labeling on the speed and accuracy of function selection performance. A significant main effect for tablet labeling was hypothesized. Full labeling was expected to produce the most efficient performance, followed by partial and no labeling. A significant main effect for sex was not expected. Trial blocks were examined as a within-subjects variable.

The analysis of variance for mean response time produced significant main effects for the block and labeling variables. As is common in response-timed tasks, performance continued to improve slightly across trial blocks. Full labeling produced the fastest response times as hypothesized, but not significantly faster than partial labeling. Response times with the unlabeled tablet were significantly slower than with the partially and fully labeled tablets. With no visual cuing provided on the tablet, the task required that the finger be moved on the touch tablet to position the cursor in the function's outlined area on the screen. The addition of labeled overlays on the

tablet significantly improved performance by changing the nature of the task from cursor positioning to direct pointing; only one brief touch in the function's outlined area on the tablet was required.

All of the subjects received the same general instruction sheet before beginning the testing session. They could perform the function selection task in whatever way was comfortable or 'natural' for them. Subjects in the no labeling group could have tried to use a direct pointing method but would have had to look at the screen to see if the cursor was in the function's outlined area; if it was not, the finger would have to remain on the touch tablet to re-position the cursor. Conversely, subjects in the partial and full labeling groups could have ignored the labeled overlays and used a cursor positioning method of selection. An additional consideration for the full labeling group was where they chose to search for the specified function (on the screen or on the tablet). The purpose of the questionnaire was to determine where the subjects in each group directed their attention during the task.

The responses to question one were relatively straightforward. Subjects in the no labeling and partial labeling groups searched for the function on the screen while half of those in the full labeling

group searched for it on the touch tablet. Response times for the full labeling group might have been faster had all of the subjects in the group searched on the tablet; this would have eliminated the extra step of finding the function on the screen before identifying the correct location on the tablet.

The responses to the second question were less clear. All of the subjects in the no labeling condition were expected to respond that they focused their attention on the screen while selecting the function; none of the subjects in the conditions with labeling were expected to respond that way. Question two may have been interpreted as asking where the majority of attention was focused during the task. A more specifically stated question could have asked if attention shifted to the finger on the tablet or remained on the screen. Even though some of the responses seemed unclear, all of the subjects in the two labeling groups were observed to shift their attention to the finger on the tablet during selection.

The two groups with labeling experienced a significant advantage in both response times and errors over the no labeling group. The analysis of variance for mean errors revealed a significant main effect for labeling only. Similar to the results from the mean response time analysis, the no labeling group was

significantly different from the partial and full labeling groups. Errors were easier to make while positioning the cursor in the unlabeled condition, especially with the finger lift-off confirmation method.

In cursor positioning tasks, methods of entry which include a separate confirmation step have been shown to have significantly lower error rates but higher response times than the lift-off method (Ellingstad et al., 1985). Adding labeled overlays in the present research significantly decreased both the error rate and response times with the lift-off entry method. Instead of trying to make the cursor positioning task more accurate by adding a confirmation step, the nature of the task itself was changed to direct pointing.

Direct pointing and eye-hand coordination are often cited as advantages of touch screens. When partial or full labeling is used, direct pointing is also possible with touch tablets. The addition of labeling makes use of the tablet's versatility and allows for a variety of tasks to be performed with the same input device.

A labeled tablet is especially useful for function selection tasks, with different methods of selection possible. Function choices must appear on the screen when partial tablet labeling is used for selection, but different displays can be used with the same outlined

overlay. In this respect, partial labeling would also be useful for proceeding through multiple menu screens. A major advantage of having one outlined overlay for multiple tasks is cost efficiency.

Alternately, full labeling on the tablet does not require choices to be listed on the screen. It can take the place of fixed function keys (those which are task-independent and require a fixed location). However, in this mode the tablet area available for other tasks would be reduced.

Further study is needed to clarify other design issues associated with tablet labeling, for instance the use of varied levels of display density. Tablet overlays which include tactile cuing could also be investigated, and the use of labeling for alphanumeric data entry tasks could be explored. Research in these areas could provide additional information for the efficient design and application of the tablet as a human-computer interface.

References

Albert, A. E. (1982, October). The effect of graphic input devices on performance in a cursor positioning task. Proceedings of the Human Factors Society - 26th Annual Meeting. Seattle, WA.

Ball, R. G., Newton, R. S., & Whitfield, D. (1980, January). Development of an off-display, high resolution, direct touch input device: the RSRE Touchpad. Displays, 203-207.

Earl, W. K. & Goff, J. D. (1965). Comparison of two data entry methods. Perceptual and Motor Skills, 20, 369-384.

Ellingstad, V. S., Parng, A., Gehlen, J. R., Swierenga, S. J., & Auflick, J. (1985). An evaluation of the touch tablet as a command and control device. Technical Report. Vermillion, SD: University of South Dakota, Human Factors Laboratory.

Foley, J. D. & Van Dam, A. (1982). Fundamentals of interactive computer graphics. Reading, MA: Addison-Wesley.

Foley, J. D. & Wallace, V. L. (1974). The art of natural graphic man-machine conversation. Proceedings of the IEEE, 62 (4), 462-471.

Foley, J. D., Wallace, V. L., & Chan, P. (1981). The human factors of graphic interaction tasks and techniques. The George Washington University, Institute for Information Science and Technology Technical Report. Washington D.C.

Gade, P. A., Fields, A. F., Maisano, R. E., Marshall, C. F., & Alderman, I. N. (1981). Data entry performance as a function of method and instructional strategy. Human Factors, 23 (2), 199-210.

Gomez, A. D., Davenport, E. W., Wolfe, S. W., & Calder, B. D. (1982, February). LMDS Lightweight Modular Display System. NOSC Technical Report 767 (TR67), Naval Ocean Systems Center, San Diego, CA.

Johnson, E. A. (1967). Touch displays: A programmed man-machine interface. Ergonomics, 10 (2), 271-277.

Kantowitz, B. H. & Sorkin, R. D. (1983). Human factors: Understanding people-system relationships. New York: John Wiley & Sons.

Kirk, R. E. (1982). Experimental design. (2nd Ed.). Belmont, CA: Brooks/Cole.

Long, J., Whitefield, A., & Dennett, J. (1984). The effect of display format on the direct entry of numerical information by pointing. Human Factors, 26 (1), 3-17.

Mims, F. M. III. (1984, May). A few quick pointers. Computers & Electronics, 64-69, 114-117.

Ng, H. H. & Puchkoff, S. J. (1982, November). Touch sensitive screens simplify data processing. Australian Electronics Engineering, 15 (11), 67, 71.

Ohlson, M. (1978, November). System design considerations for graphics input devices. Computer, 9-18.

Pedhazur, E. J. (1982). Multiple regression in behavioral research. (2nd Ed.). New York: Holt, Rinehart and Winston.

Pfaff, G., Kuhlmann, H., & Hanusa, H. (1982). Constructing user interfaces based on logical input devices. Computer, 15, 62-68.

Pfauth, M. & Priest, J. (1981, October). Person-computer interface using touch screen devices. Proceedings of the Human Factors Society - 25th Annual Meeting. Rochester, New York.

Pobgee, P. J. & Parks, J. R. (1971). Applications of a low-cost graphical input tablet. Proc. IFIP Congress, TA-4, 169-173.

Ramsey, H. R. & Atwood, M. E. (1979, September). Human factors in computer systems: A review of the literature. (Tech. Rep. SAI-79-III-DEN). Englewood, CO: Science Applications. (DD No. ADA075679).

Ritchie, G. J. & Turner, J. A. (1975). Input devices for interactive graphics. International Journal of Man-Machine Studies, 7 639-660.

Scott, J. E. (1982). Introduction to interactive computer graphics. New York: John Wiley & Sons.

Seibel, R. (1972). Data entry devices and procedures. In H. P. Van Cott and R. G. Kinkade (Eds.) Human engineering guide to equipment design (rev. ed.). Washington: U.S. Government Printing Office.

Sutherland, I. E. (1974, April). Three-dimensional data input by tablet. Proceedings of the IEEE, 62 (4), 453-461.

Swezey, R. W. & Davis, E. G. (1983, November). A case study of human factors guidelines in computer graphics. IEEE CG & A, 21-30.

Turner, J. A. & Ritchie, G. J. (1973). The Analog Touch Panel - a finger-operated computer graphic input device. Society for Information Display, International Symposium Digest, 4, 14-15.

Whitfield, D., Ball, R. G., & Bird, J. M. (1983). Some comparisons of on-display and off-display input devices for interaction with computer generated displays. Ergonomics, 26 (11), 1033-1053.

Winer, B. J. (1971). Statistical principles in experimental design. (2nd Ed.). New York: McGraw-Hill.

Appendix A

Informed Consent Form

You are invited to participate in the function selection study conducted at the Human Factors Laboratory in the Psychology Department. Your participation is voluntary, but you must be of legal age (18 years or older) and legally competent to give this consent.

If you agree to participate, you will be seated in front of a monitor and a touch tablet. The function selection task involves using the touch tablet to select a series of specified functions. The purpose of the study is to determine if performance differences exist due to the use of different experimental variables, but there will be no direct benefit to you. The task will take approximately 20 minutes.

No deception will be used and there are no risks involved. All of the data will be kept strictly confidential; your name will not be associated with your data. You will be given a copy of this consent form to keep.

You are free to withdraw from the experiment at any time, but then you will not receive the 2 points of extra credit. If you have any questions, please ask them now. If you have any questions later, you can reach Jean Gehlen at 677-5295.

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Signature of participant   date

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Signature of witness   date

Appendix B

Instructions for the Function Selection Task

The task consists of selecting the function specified in the center of the screen. Selecting the function requires positioning the cursor on the screen (a plus sign: +) anywhere in the specified function's outlined area. This is done by using the index finger of your dominant hand to touch the area on the tablet that corresponds to the specified function's area.

Once you have touched the tablet, maintain a constant pressure on it and do not lift your finger off until it is positioned where you want it. Very little pressure is needed. When you lift your finger off of the tablet surface your selection will be confirmed (recorded). After a 2 second delay another function will be specified in the center of the screen.

The computer records errors and times each selection separately. Timing starts when the function first appears and ends when you lift off your finger. Please work as fast and as accurately as possible.
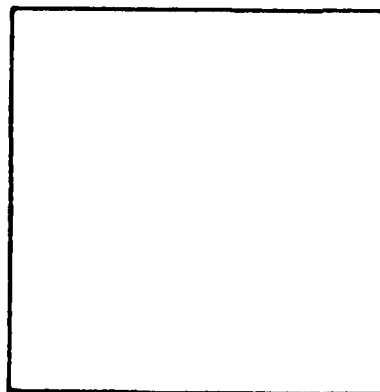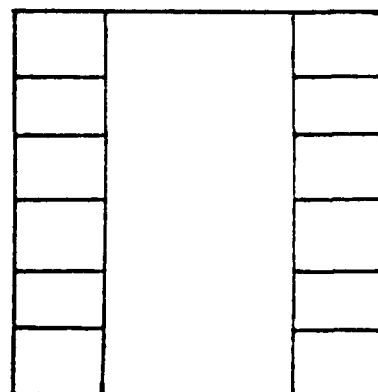
Appendix C

Display Layout and Labeling Conditions

Help		Copy
Edit		Graph
Name		Table
Calc	Select: Help	Page→
Go To		←Page
Clear		Mode

Display Layout and Full Labeling Condition

No Labeling

Partial Labeling

Appendix D

Function Selection Study Questionnaire

Subject Number _____

1. After reading the specified function in the center
   of the screen, where did you search for it?

   _____ on the screen

   _____ on the touch tablet

2. While selecting the function, where did you focus
   your attention?

   _____ on the touch tablet

   _____ on the screen